REPORT ON INVESTIGATIONS
OF SOILS
BRUSH WELLMAN, INC.'S
TOPAZ MINING PROPERTY

023/003

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1.0 EXECUTIVE SUMMARY

Recent investigations by JBR Consultants Group of the soils properties of the Brush Wellman, Inc., Topaz Mine Property mine spoils have shown that they have salinity and structural characteristics which are detrimental to plant growth. Comparisons of soils chemistry data obtained in 1978 with the recent data indicate that the salinity, and to a lesser degree, the sodicity (exchangeable Na content) of these materials decreases over time under the influence of weathering. This process appears to be very time consuming even though the last three to four years have generally been wetter than normal. The weathering effect appears to reduce the original severe salinity hazard to levels which can be tolerated by appropriate plant species. The levels of exchangeable sodium are not reduced as significantly and as a result, the soils tend to have physical properties (dispersed clays) which are very adverse to the germination and survival of even the most salt-tolerant plants.

The use of chemical amendments, accompanied by leaching with irrigation water, to reduce the sodicity values within the root zone does not appear to be a viable method of mitigating this problem. The use of chemical amendments with only natural weathering to induce leaching has been shown by others to be only marginally beneficial. The most effective means of reclaiming saline-sodic spoils has been shown to include covering them with topsoil and reseeding the topsoil. The amount of topsoil required to produce reasonable vegetation cover levels can be quite thin; even 2" of topsoil has been show to be effective. The problem with topsoiling saline-sodic spoils is that over time, the soluble salts from the spoil will tend to migrate upward into the topsoil and reduce it's productivity. It is difficult to predict the potential severity of this effect from the present research but it would likely result in a permanent vegetation cover level which is less than that required by the DOGM regulations. One obvious solution to this problem would be to cover the spoils with a thick topsoil layer.

Topsoil has not been stockpiled from the areas presently disturbed and preliminary observations indicate that suitable sources of topsoil for reclamation work are not readily available in the vicinity of the present disturbances. It is recommended therefore that the present disturbances should not be topsoiled or revegetated. Suitable sources of soil materials may exist in the areas of proposed mining activities. Future mine disturbances could therefore be preceded by stockpiling the available topsoil. This material would then be available for covering the new dumps and revegetation would initially be more successful. The long-term vegetative cover levels resulting from this practice will likely be less than that required under the DOGM standards and allowance should be made in the reclamation plan to accommodate this possibility.

2.0 INTRODUCTION

2.1 Operations Description

Beryllium was discovered in the volcanic tuff beds around Spor Mountain, about 40 miles northwest of Delta, Utah, in late 1959 and 1960. During the period 1960 to 1967 extensive geologic exploration studies in the area to the west of Spor Mountain identified commercial quantities and grades of beryllium ore. In 1968, Brush Wellman Inc. began stripping on the first open pit, known as the Roadside Pit (Fig. 1), and also began construction of the Delta Beryllium Mill. Other open pits were sequentially mined as the following schedule indicates:

Blue Chalk North	1971-1972
Fluro #1	1974-1975
Taurus	1979
Sigma Emma	1979-1980
Roadside II	1981
Rainbow #1	1985
Blue Chalk South #1	1985-1986

During the course of the mining the overburden is stripped off of the ore bearing tuff and wasted on mine dumps which are constructed adjacent to the pits. The overburden primarily consists of rhyolite which has been altered in it's lower section. The upper section of the tuff, which is below 0.30% BeO, is also removed to expose the ore zone of the tuff. This upper tuff material is also placed on the mine dumps and ,because it usually is the last material to be placed on the dumps, it covers the surface of the dumps. Following the mining of the ore, each pit is left as is. The final condition of the pits exposes the resistant rhyolite in the highwall and the lower section of the tuff on the hanging wall.

2.2 Objectives of the Study

The Utah Mined Land Reclamation Act requires that mining operations which are conducted after July 1, 1977 receive an approval of a mining and reclamation plan from the Division of Oil, Gas and Mining (DOGM). One of the reclamation requirements of the DOGM Rules is the revegetation, where possible, of all areas disturbed by mining activities. In it's application, Brush Wellman proposed that the tuff material which covered the mine dumps be used as a growth medium for the revegetation. This practice was endorsed by the DOGM in a letter dated January 1, 1977. In 1977 and 1978 the DOGM sampled the tuff materials from the dumps and had soils fertility tests conducted on them. The results of this test work indicated that the tuff was a saline-sodic material which would be difficult to revegetate due to it's low permeability and salinity. The adverse characteristics of this material for growth of vegetation were not reported to Brush by DOGM and it proceeded with the design of a revegetation test plot program for two of the tuff covered dumps. Under the DOGM's direction Brush Wellman constructed the test plots in 1978. The results of the test plot program to date have been discouraging with very little growth (5.0-9.2% cover) being present after seven years, the last four years of which have been above normal precipitation years for most areas of the State.

To determine the extent and severity of the potential problem related to revegetation of the tuff, JBR Consultants Group has completed a comprehensive sampling and analyses program of the dumps at the Brush Wellman Topaz Mine. The objectives of this work were twofold: 1) to determine if the tuff at the revegetation test plots had decreased in salinity due to weathering and leaching since the DOGM last sampled it and, 2) to characterize the soil chemistry of the mine dump and open pit foot wall surfaces. The analysis was reviewed by Dr. Jerome J. Jurinak, Professor of Soil Science, Department of Soil Science and Biometeorology, Utah State University.

2.3 Methodology

On June 20 and 21, 1985 most of the dumps and foot walls were inspected and sampled with grab samples (Fig. 1) of the materials that would be used for growth medium, assuming that no topsoiling would be utilized. Most of the soil samples were taken as composite samples at arbitrary depth intervals. The depth intervals were normally 0-6" and 6-12" for each location except at the revegetation test plots where at least three 6" samples were taken from 18" holes. The lower portion of the rhyolite overburden, which has been altered to a reddish brown material ("brown zone"), was sampled with separate composite channel samples in two open pits.

Additionally, samples were obtained of the in-situ alluvium in three locations on the Brush Wellman property and of the test plot soils at the Valley Asphalt, Lava Bench Mine located roughly 25 miles east of the Brush Wellman mine. This other mine has been partially reclaimed and also was the site of a revegetation test plot program designed by the DOGM.

All samples were described visually in the field and placed in plastic sample bags. The samples were sent to the Soil, Plant and Water Analysis Laboratory at Utah State University, Logan for the following analyses:

-pH

-Conductivity (ECe)

-Sodium Adsorption Ratio (SAR, calculated from the ratio of soluble sodium to soluble calcium and magnesium in the saturation extract)

-Saturation Percentage (SP, the soil-moisture content of the soil at saturation)

-Exchangeable Sodium Percentage (ESP, the percentage of the cation exchange capacity satisfied by sodium. This value was calculated from the SAR.)

-Soluble P,K,Ca,Mg,and Na (determined from analysis of the saturation extract)

-Texture, on selected samples

3.Ø GEOLOGY AND MINERALOGY

Because the materials intended as a growth medium are essentially barren rock, subjected to varying degrees of alteration due to geologic processes and weathering, it is appropriate to review the geology and mineralogy of the materials as it pertains to their use as soil materials.

The overburden materials removed from the pits represent the Spor Mountain Formation which consists of two informal members, the beryllium tuff and an overlying porphyritic rhyolite.

The beryllium tuff contains five facies consisting of varying percentages of tuff, tuffaceous breccia, clasts of altered and unaltered carbonate rocks, bentonite, altered pumice and nodules made of different amounts of silica, iron and manganese oxide and, fluorite (Lindsey, 1982, Montoya et.al., 1962). Work by Montoya et.al. indicated the following estimated mineralogic composition of the tuff:

Mineral	Secs. 5 and 8	Sec. 9
Montmorillonite	35-45%	Ø-5%
Berylliferous Saponite	-	35-4Ø
Quartz	13-17	15-2Ø
Cristobalite	15-2Ø	-
Tridimite	-	3-5
Volcanic glass	-	5-1Ø
Feldspar	1Ø-2Ø	15-2Ø
Fluorite	5-1Ø	5-1Ø
Iron-manganese oxides	2-4	2-4
Hydrated Bertrandite	1-3	-
Other minor constituents	1-2	1-2

The mineralogy of the tuff controls it's physical and chemical properties. The bulk of the material is comprised of clay minerals, either montmorillonite or saponite, or micro-crystalline cristobalite, tridymite, glass, fluorite, and hydrated bertrandite. The fine nature of this mixture contributes to low hydraulic conductivities, especially under the influence of weathering which would tend to break down the minerals. The clay minerals, particularly montmorillonite, in a sodic environment contribute to dispersive soil characteristics. Any moisture that enters the material would tend to cause the clays to swell and further reduce the hydraulic conductivity.

The mineralogy of the tuff indicates that the modal analysis would be dominated by silica, aluminum and alkali oxides while relatively deficient in basic metal oxides. Montoya et. al. determined that the average chemical analysis of 9 samples of tuff was as follows: Al_2O_3 9.9%, SiO_2 61.8%, MgO 3.2%, Fe_2O_3 1.6%, MnO_2 Ø.9%, K_2O/Na_2O 15.4%, CaF_2 6.3% and BeO plus others equal to Ø.9%. This parent material would produce a soil which was relatively high in monovalent cations, e.g Na and deficient in divalent cations thus tending to produce an elevated SAR and ESP. This means that the exchangeable cation sites of the soil clay minerals would likely be predominated by sodium which would enhance the dispersivity of the clays.

4.Ø SAMPLE SITE DESCRIPTIONS

The locations of the soil samples are shown on Figure 1. The location site numbers on the map key to the sample descriptions included in Table 1 below.

Table 1. Soil Sample Descriptions

Location	Description
1	Roadside Dump test plot, west slope. BW-1 north end of plot, tuff, 18" composite BW-2 same hole, tuff, Ø-6" BW-3 same hole, tuff, 6-12" BW-4 same hole, tuff, 12-18" BW-5 center of test plot, tuff, Ø-4" BW-6 same hole, tuff, 4-14" BW-7 south end of test plot, tuff, Ø-6" BW-8 same hole, tuff, 6-12" BW-9 same hole, tuff, 12-18"
2	Roadside Pit, northeast side BW-1Ø foot wall, tuff, Ø-6" BW-11 same hole, tuff, 6-18"
3	Fluro Pit, northeast side BW-12 foot wall, tuff, Ø-18"
4	Fluro Pit, northwest side BW-13 composite channel sample, brown zone
5	Blue Chalk North Dump, test plot BW-14 top of dump, rhyolite w/ tuff, Ø-4" BW-15 same hole, rhyolite, 4-9" BW-16 top of south slope, tuff, Ø-6" BW-17 same hole, tuff, 6-12" BW-18 same hole, tuff, 12-18" BW-19 base of south slope, tuff, Ø-6" BW-2Ø same hole, tuff, 6-12" BW-21 same hole, tuff, 12-18"
6	Blue Chalk Pit, east side BW-22 hole in foot wall, tuff, Ø-6" BW-23 same hole, tuff, 6-18"
7	Alluvium BW-24 alluvium, Ø-4"

8	Taurus North Dump BW-25 top of dump, tuff, Ø-12"
9	Taurus South Dump BW-26 top of dump, brown rhyolite, Ø-12"
1Ø	Future Camp Pit Site BW-27 topsoil, Ø-6" BW-28 same hole, topsoil, 6-12"
11	Monitor Pit, west side BW-29 channel sample, alluvium, Ø-3Ø" BW-3Ø same channel, alluvium, 3Ø-18Ø"
12	Monitor Pit, west side BW-31 channel sample, brown zone, 18Ø-24Ø"
13	Fluro Dump BW-32 west slope, center, rhyolite, Ø-12"
14	Fluro Dump BW-33 dump top, south end, rhyolite, Ø-12"
NA	Valley Asphalt, Lava Bench Mine, sandy soil BW-34 center of east aspect test plot, Ø-12" BW-35 south aspect test plot, Ø-12"

In general, the tuff throughout the property was similar in it's characteristics. The top 4-6" was dry and friable, either as a loose powder or as a granular "popcorn" texture. Below this dry surface layer the tuff generally is a dense, plastic clay or sandy clay with few rocks. This lower material was usually moist.

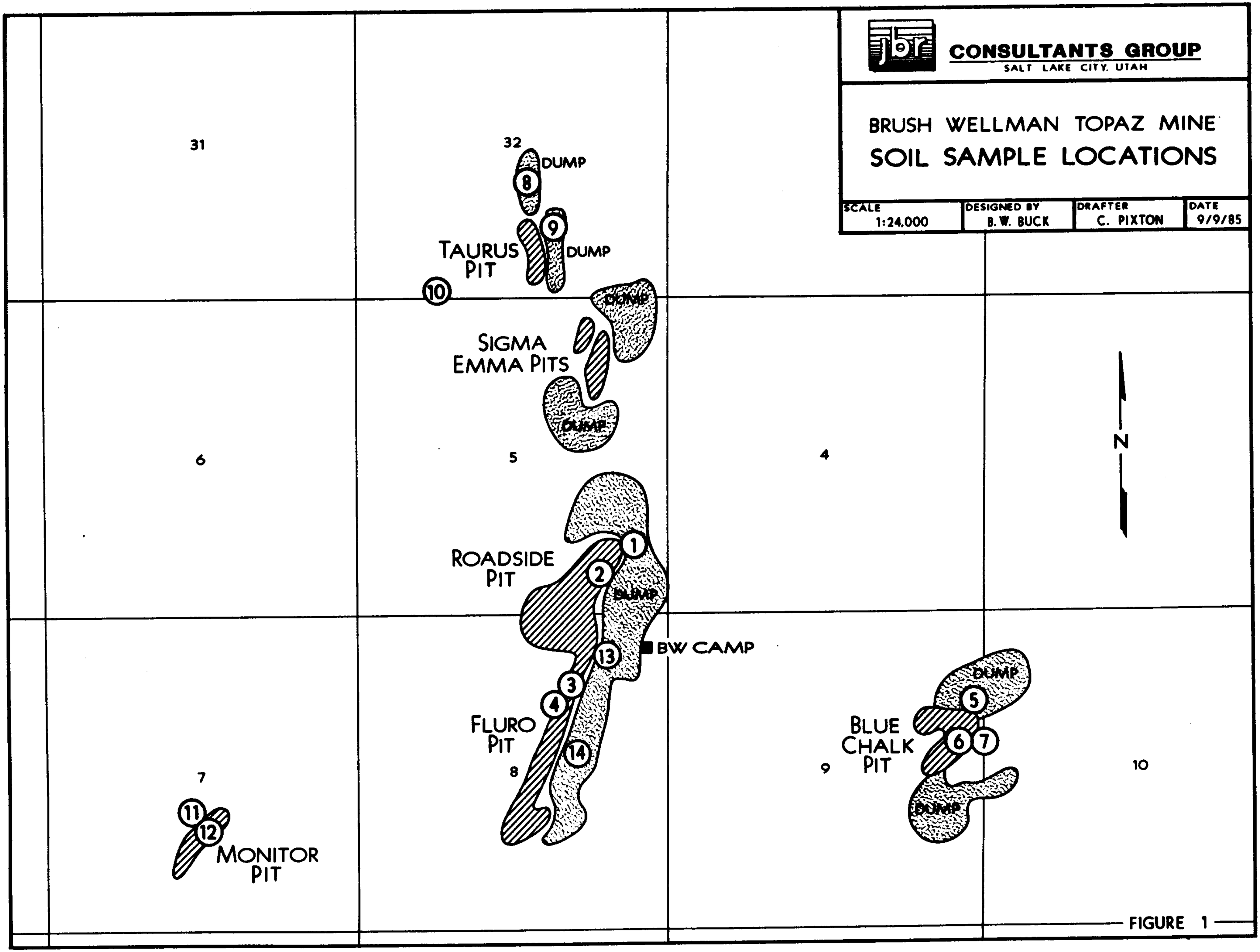
jbr CONSULTANTS GROUP
SALT LAKE CITY, UTAH
BRUSH WELLMAN TOPAZ MINE
SOIL SAMPLE LOCATIONS
SCALE 1:24,000
DESIGNED BY B. W. BUCK
DRAFTER C. PIXTON
DATE 9/9/85
31
32
DUMP
8
9
DUMP
TAURUS PIT
10
DUMP
SIGMA EMMA PITS
DUMP
6
5
4
N
ROADSIDE PIT
1
2
DUMP
BW CAMP
13
3
4
FLURO PIT
14
8
9
DUMP
5
BLUE CHALK PIT
6
7
DUMP
10
7
11
12
MONITOR PIT

FIGURE 1

5.0 SOILS DATA ANALYSIS

There are three sets of data available for the tuff material. The first data represents analyses from six samples collected by the DOGM in February of 1977. This data is included in Table 2 and in the Appendix. It includes samples which were obtained from the Fluro, Roadside and Blue Chalk dumps. Only pH, lime, ECe, P, and K were analyzed for and the lack of Ca and Mg results prevents the calculation of the SAR and ESP values. The ECe results did indicate that the soil had an elevated salinity.

The second set of data represents a site of 16 samples taken by the DOGM in August of 1978 on the revegetation test plots located on the tops and slopes of the Roadside and Blue Chalk dumps. This data set is complete with K, P, Ca, Mg, ECe, pH, lime, and SAR and is included here as Table 3. The EC_e data coupled with the SAR values of most of the soils place them in the category of saline-sodic materials and an appreciable decrement in plant growth can be expected if plant growth is established. The initial plant establishment is considered the major barrier.

The most recent data set is that collected by JBR Consultants in the course of this investigation. It includes 33 samples from the Topaz mine site and 2 samples from the Asphalt Ridge Mine (Table 4). The analyses included pH, ECe, SAR, SP, ESP, P, K, Ca, Mg, and Na.

Table 2. Soils Analyses Data from 1977.

Sample	lime	pH	ECe	P	K
Fluro 2"	+	7.8	5.2	1.2	>320
Fluro 6"	+	8.4	7.4	1.2	>320
Roadside 2"	+	8.1	4.0	1.1	83
Roadside 6"	+	7.8	5.6	0.1	89
Blue Chalk 2"	+	7.5	9.1	0.6	84
Blue Chalk 6"	+	8.1	2.7	0.6	75

Table 3. Soils Analyses Data from 1978.

Sample	lime	pH	ECe	P	K	Ca+Mg	Na	SAR
Blue Chalk Dump Test Plot								
Slope A	0	8.1	.0	4.0	218	1.2	9.1	12
Slope B	0	8.0	.8	3.7	>320	0.7	7.4	13
Slope C	0	7.4	8.9	3.7	277	24.6	65.2	19
Slope D	0	7.4	4.9	2.5	>320	14.3	33.0	23
Top A	+	7.3	45.0	4.2	>320	139.0	313.0	33
Top B	++	7.5	30.0	3.3	268	93.6	196.0	29
Top C	++	7.3	57.0	3.7	228	215.0	374.0	36
Top D	++	7.8	22.0	4.0	187	75.1	134.0	22
Roadside Dump Test Plot								
Slope A	+	7.9	8.0	3.0	>320	10.8	60.4	26
Slope B	+	7.8	16.0	3.5	>320	31.7	123.0	31
Slope C	+	7.6	31.0	5.0	>320	103.0	200.0	28
Slope D	++	8.0	46.0	3.7	>320	148.0	322.0	38
Top A	+	8.4	0.8	4.7	>320	1.3	7.8	10
Top B	0	8.3	0.7	4.8	>320	0.7	7.4	13
Top C	0	7.5	9.7	4.4	>320	43.3	65.2	14
Top D	0	7.7	1.9	5.8	>320	2.9	15.7	13

Note: P and K are expressed as ppm: Ca, Mg and Na as Meq/l, Ec_e as mmhos/cm

Table 4. Soils Analyses Data from 1985.

Sample	pH	ECe	SAR	SP	ESP	P(ppm)	K(ppm)	Ca(ppm)	Mg(ppm)	Na(ppm)
BW 1	8.1	7.8	29.20	50.1	30.46	<0.5	489	83.5	42.0	1310
BW 2	8.7	0.8	14.83	48.8	18.20	<0.5	444	5.5	1.5	152
BW 3	8.4	4.3	28.82	46.2	30.18	<0.5	468	24.6	10.7	3650
BW 4	7.9	24.5	29.55	42.1	30.71	<0.5	537	612.0	331.0	3650
BW 5	8.1	0.5	6.10	53.1	8.38	<0.5	287	10.3	4.9	95
BW 6	8.3	0.3	5.06	59.8	7.05	<0.5	205	7.3	2.7	63
BW 7	8.4	0.6	7.88	49.1	10.57	<0.5	489	7.2	3.2	101
BW 8	8.5	0.5	7.69	45.1	10.34	<0.5	501	11.0	2.4	108
BW 9	8.9	0.6	11.30	44.2	14.49	<0.5	465	6.8	1.6	126
BW10	8.2	1.0	8.86	63.8	11.73	<0.5	399	14.8	6.6	163
BW11	8.3	0.7	7.65	24.9	10.29	<0.5	371	10.3	4.7	118
BW12	7.8	29.4	42.80	83.9	39.10	0.6	507	555.0	279.0	4950
BW13	7.7	21.0	5.39	70.5	7.48	0.5	114	4480.0	620.0	1450
BW14	8.0	9.1	21.79	84.1	24.63	1.2	231	213.0	86.0	1490
BW15	8.0	11.4	22.59	77.7	25.31	1.7	220	292.0	115.0	1800
BW16	7.8	10.2	18.80	78.2	22.00	0.7	214	298.0	120.0	1520
BW17	7.7	10.7	16.45	82.4	19.79	0.9	208	364.0	142.0	1460
BW18	7.8	11.4	14.96	84.4	18.33	0.6	201	468.0	179.0	1500
BW19	8.5	0.5	5.34	107.6	7.42	<0.5	256	7.6	2.2	65
BW20	8.3	1.3	12.68	83.4	15.98	<0.5	205	13.4	5.1	215
BW21	7.9	2.3	14.92	82.4	18.29	0.5	195	30.6	12.1	385
BW22	8.5	0.9	6.00	77.8	8.26	0.5	167	24.9	7.2	132
BW23	8.2	1.4	5.90	76.2	8.13	0.5	115	43.3	12.8	172
BW24	8.5	0.9	5.82	34.9	8.03	3.0	421	32.9	7.1	141
BW25	7.7	11.3	22.28	94.3	25.05	0.5	477	260.5	213.0	2000
BW26	8.4	0.4	6.87	77.0	9.34	0.6	138	5.5	2.0	74
BW27	8.5	0.5	3.33	24.7	4.76	2.5	334	18.6	6.8	66
BW28	8.7	0.5	3.63	23.7	5.16	1.8	276	16.4	6.2	68
BW29	9.8	0.6	9.09	32.9	12.00	1.9	104	12.2	2.3	132
BW30	9.3	0.4	5.35	28.3	7.43	o.5	129	9.1	5.3	82
BW31	8.6	128.0	152.86	33.1	69.59	0.5	318	384.0	590.0	20400
BW32	8.1	13.0	23.55	77.8	26.10	0.5	135	327.9	210.0	2220
BW33	8.1	6.6	15.56	40.9	18.92	0.5	249	166.3	60.0	920
BW34	8.4	1.1	4.47	27.4	6.28	0.5	108	49.3	11.5	134
BW35	8.1	5.6	7.20	45.0	9.75	4.5	406	444.0	72.0	620

6.0 DATA INTERPRETATION

6.1 General

The data from the three sampling episodes indicate that the tuff material has the characteristics of a saline and sodic soil. A saline soil is one where the EC_e of the saturation extract is > 4 mmhos/cm at 25° C. A sodic soil is traditionally related to an ESP of >15 or SAR >13 (Richards L.A. ed., 1954). Saline-Sodic systems have a combination of these properties and have variable characteristics depending upon the amount of soluble salt present, the relative amounts of available Ca and Mg, and the soil texture.

In arid areas the salinization of soils takes place usually through the net upward movement and evapotranspiration of soil water which tends to accumulate salts in the upper section of the soil profile. In mine spoils, salinity can be an inherent characteristic of the material itself caused by geochemical processes. In this later case, the salinity problem can be aggravated by the further concentration of soluble salt in the upper soil section due to evaporation. The problem of the revegetation of a saline soil is that the presence of excess salts in the soil solution reduces the plant available moisture. This means because the osmotic potential of the soil water is added to the capillary potential of the matrix thereby increasing the energy required by the plant to extract water from the soil. This conditions is particularly troublesome in arid regions where vegetation is under moisture stress throughout most of the year. This effect is most pronounced during the germination stage of plants when a plentiful source of soil moisture is essential. Although the main effect of soil salinity is it's limitation of soil-moisture, certain salts can be toxic to specific plant species when present in sufficiently high concentrations (Hausenbuiller, 1972). The classic example is the element boron, an essential nutrient that becomes phytotoxic with increasing concentration. With less direct evidence large excesses of Na may be phytotoxic but increasing Na to excessive amounts in soils also results in Ca-deficiency which has been mistaken for Na-toxicity. The presence of some salts also reduces the activity of soil microorganisms which affects the availability of nutrients to plants (Sommerfeldt and Rapp, 1982).

A sodic hazard in soils refers to the condition where sodium satisfies an above-normal percentage of the cation exchange capacity. The normal exchangeable cations that are adsorbed on the soil particles are Ca, Mg, Na, and K. The exchangeable cation balance of the soil controls the condition of the clay particles. When the exchangeable positions are saturated with

Ca, Mg, or K the clays tend to be flocculated and the soil has good permeability with a loose structure. When exchangeable Na constitutes 10-15% of the exchange capacity, the clay tends to swell and disperse leading to a breakdown of the physical structure of the soil matrix. This condition greatly restricts water and air entry and movement in the soil. The structure becomes single grained and dense. Plant growth is limited or prevented by these conditions.

When excess soluble salts accumulate in a soil, sodium frequently becomes the dominant cation in the soil solution. This often occurs when the salinity is caused by evaporation of soil moisture in arid regions which tends to concentrate calcium sulfate and calcium carbonate above their solubility limits and they precipitate as solid compounds. Thus the relative abundance of divalent cations in the soil solution is reduced and sodium becomes the dominant cation in both the soluble and exchangeable state (Richards L.A. ed., 1954). In mine spoils, the geochemical processes which accompanied the ore formation may be often represented by high sodicity. Regardless of the cause, sodic soils are not conducive to plant growth because of their dispersed physical condition which reduces the hydraulic conductivity and infiltration from precipitation and movement in the profile is nil. The result is a massive dense soil structure which eliminates plant establishment. The adverse soil condition overrides any soil fertility deficiency which is also associated with sodic soils.

6.2 Test Plot Soils

The Roadside Dump test Plots established in 1978 were revisited and sampled in this study. Since 1978 the test plot on the top of the dump had been covered with an additional lift of waste rock as so was destroyed. The west-aspect sloping test plot survived and was resampled in three locations at it's north end in the middle of the exposed slope, near the top of the slope, and at the south end of the plot. The results from the north test pit showed a high salinity (ECe= 7.8) and SAR (29.2) which would be expected to severely limit the revegetation potential (Table 4). The salinity and sodicity values increased with depth over the 18" interval sampled which either indicates that the salts are being leached by the effect of recharge or that the dispersed clays are being washed down into the soil profile. The salinity, SAR, and ESP are lower than those measured in 1978. This probably indicates that the minerals are weathering and releasing their salts which are then leached out of the soil profile. The rapidly increasing ECe and SAR values with depth indicates that the restricted infiltration and low hydraulic conductivity of the soil prevents the salts from being effectively removed from the root zone.

The test pits at the top and south end of the test plot exposed soils which visually were more weathered than at the north test pit location. The salinities and sodicities are lower than those measured in the north test pit soils and are also lower than those measured in 1978. This indicates that the weathering has been more complete in these test pit locations and that the salts have been leached out of the soil profile sampled.

A similar pattern is evident at the Blue Chalk Dump test plots. The test pit location sampled on the top of the dump shows high salinity and sodicity values which increase with depth. Compared to the 1978 data, the tuff now on the top of the dump has lower salinity and sodicity values. This suggests that salt is being leached from the tuff material at this location and is being moved into the more permeable underlying dump.

The test pit located halfway down the south-aspect slope test plot shows high salinity and sodicity values. The 1985 conductivity values are higher than the 1977 values and the SAR values decrease with depth. These data indicate that the flux of salts in this location is upward, probably related to the south aspect which would increase the evaporation rate. At this location, the salinity and sodicity have increased since 1978 which also suggests that the salts liberated by weathering are not being leached out of the soil profile but are being concentrated.

The test pit location at the bottom of the same slope indicates that the salinity and sodicity increase with depth. The values are lower than those measured in 1978. The salinity values are low but the SAR/ESP values are still sufficient to cause problems with vegetation growth. The greater amount of leaching that has occurred at this location relative to the test pit located higher on the slope, may be due to the greater amount of moisture available lower on the slope.

The data obtained from the test plots in 1978 and 1985 indicate that the tuff is a saline-sodic material that readily weathers to a clay or sandy clay soil. When placed on the surface, this material gradually is leached of it's soluble salts which reduces the Ec_e from the initially high ECe levels of over 16 mmhos/cm to lower levels when the salts are apparently moved down into the soil profile. Where the tuff is exposed to extremes of net evaporation on south aspect slopes, the soluble salts tend to concentrate toward the top of the soil profile. The net conductivity levels following up to 16 years of weathering at certain locations are still in the range were only the more salt-tolerant plants can be expected to survive.

The exchangeable sodium content of the clay fraction is less affected by the weathering process. The SAR values since 1978 have generally reduced in response to the decreasing soluble salt values but to a lesser degree. The SAR values that remain following years of weathering are largely in the range where the montmorillonite clays can be expected to be dispersive. This produces dense soils of low permeability which limit the recharge of soil moisture, impede root growth, and produce surface crusts. This poor soil structure is obvious in the field and is considered a major factor for the poor revegetation success of the test plots.

6.3 Altered Rhyolite

The lower portion of the highwalls in various pits expose altered rhyolite which appears to be soft enough to possibly be used as a growth medium cover for the dumps. This material was sampled in the Fluro and Monitor pits using composite channel sample techniques. Both materials have Ec_e values which are in the phyto-toxic range. The nature of these soluble salts is different in the two locations with the Fluro Pit material being dominant in Ca (4480 ppm) while the Monitor Pit material is dominated by very high in soluble Na (20400 ppm). The SAR values reflect the ratio of Na to (Ca + Mg) concentrations with the Fluro Pit material displaying a low SAR (5.39) while the Monitor Pit has an extremely high SAR value (152.86).

The Monitor Pit material clearly is not suitable for reclamation practices due to it's elevated salinity and SAR. The material from the Fluro Pit may be suitable following a period of weathering during which the soluble salts could be leached out but this would need to be verified by further sampling and possibly leaching tests. The heavy texture (SP=71) of this material suggests this would be a long term process.

6.4 Foot Wall Tuff

The foot wall tuffs in the Roadside, Fluro, and Blue Chalk Pits were sampled. The Roadside and Blue Chalk samples showed low ECe (0.7 and 1.4) and SAR (7.65 and 6.0) values that were in the range normally considered to be negligible as far as revegetation problems are concerned. The Fluro Pit sample is much different with ECe (29.4) and SAR (42.8) values. The EC_e values indicate a definite salinity hazard with little chance of vegetation survival. All of the sample sites were similar in that the material had a dry, fluffy or "popcorn" surface layer a few inches thick underlain by clay or sandy clay which in the case of the Roadside and Blue Chalk pits was very dense. Volunteer revegetation of these slopes was almost non-existent which indicates severe revegetation difficulty.

The data from the foot wall samples are difficult to explain because the lower ECe and SAR values in the Roadside and Blue Chalk Pits may be relics of the initial mineralizing conditions in these pits which may have concentrated the salts in the uppermost section of the tuff. The possibility exists that the initial ECe and SAR values were high but have been decreased by weathering and leaching in these older pits relative to the younger Fluro Pit but there is no control on this hypothesis due to the lack of earlier soil samples. Regardless of the soil chemistry, the very poor soil structure is certainly a problem for revegetation and the west-aspect foot wall slopes will tend to be relatively dry which will further impede revegetation success.

6.5 Other Dumps

The mine dumps of the Fluro and Taurus pits were also sampled. The sample of tuff material (BW25) from the north dump of the Taurus Pit displayed the typical high ECe (11.3) and SAR (22.28) values which are high enough to seriously affect revegetation. The sample of the brown rhyolite from the south Taurus Dump displayed low ECe (Ø.4) and SAR (6.87) values which would be little problem for revegetation.

Samples from the Fluro dump appeared to be mostly rhyolite yet had ECe values (6.6-13.Ø) which could be tolerated by salt-tolerant plants only and showed high SAR values of (15.56-23.55). This may indicate that the top surfaces of this dump contain either tuff or "brown zone" material.

The rhyolite is not always deleterious to vegetation. The top surface of the Blue Chalk Dump, in the vicinity of the test plot, shows that the native vegetation is spreading readily into the dump where the tuff has not been incorporated into the hard, grey rhyolite. This indicates that the rhyolite overburden itself is suitable material and can be directly revegetated as long as the tuff and "brown zone" materials are not present.

The results of the additional dump sampling indicates that the visual appearance or age of the rhyolite material is not sufficient to categorize it's ECe and SAR values. The ECe and SAR values for the tuff at the Taurus Dump seem to confirm that this material is generally deleterious to vegetation, particularly when it has been recently removed from the pit. The disparity between the ECe and SAR values of the rhyolite at the Taurus vs. the Fluro dumps suggests that any rhyolite waste rock should be sampled to determine it's chemical properties prior to attempting revegetation.

6.6 Native Soils

Samples of the native soils were obtained from the area just east of the Blue Chalk Pit, in the high wall of the Monitor Pit and also at the location of the future Camp Pit. In general, the native soils display none of the salinity and sodicity problems of the overburden materials. The gradation of the near-surface soils sampled at the Blue Chalk and Camp sites is adequate for revegetation use. The thicker soil and subsoil alluvium at the Monitor site contains less fines and would be less desireable for reclamation use. This thicker subsoil section is likely to also occur beneath the depth sampled at the Camp site. The soils analyses indicate that additional phosphorus and nitrogen would need to be added as a fertilizer at a rate of 50 lbs. per acre. The addition of organic matter such as straw which is disked into the top surface of the topsoil will also aid in the revegetation success.

7.0 RECOMMENDATIONS

The normal reclamation technique for saline soils consists of removal of the soluble salts through leaching. Several conditions are required to accomplish this. First, water for irrigation must be available in sufficient quantities and be of adequate quality (low TDS). Secondly, the water must be applied uniformly over the area to be leached without running off. This is usually accomplished by ponding the water over the leveled saline soil. The final condition is that the permeability of the soil must be high enough to enable the saline leachate to move below the root zone during the period of leaching. The salt must be leached a given depth below the root zone because eventual upward moisture movement caused by evapotranspiration will move the salt upward in the profile. This last condition requires that in saline-sodic systems the sodic reclamation must proceed under high salt concentrations to prevent clay dispersion.

The removal of soluble salts from the tuff material by irrigation leaching is obviously not possible at the Topaz Mine. First of all, there is no ready surface source of a suitable quantity nor the means to distribute it economically around the property. The amount of water necessary would be very large as is indicated by the experience of Reeve et. al. (1948) who found that it took the application of 4 feet of water on a saline-sodic soil near Delta, Utah to reduce the ECe from a value of about 30mmhos/cm to 5mmhos/cm. While unsaturated reclamation would require only 1/3 the water the opportunity to irrigate with groundwater is not feasible due to the poor quality (high TDS) of the groundwater in the vicinity of the mine (personal communication with L. Davis, Brush Wellman, Inc.).

The removal of exchangeable sodium from sodic soils is normally accomplished with the addition of an amendment which will supply soluble Ca. This soluble Ca will replace the Na in the clays and lower their dispersivity. This results in an increase in the permeability of the soil, a reduction in the strength of the surface crusts, and generally makes the soil more readily penetrable by plant roots. The most common reclamation method is the addition of a source of Ca to replace exchangeable Na ion. This is usually the amendment $CaSO_4.2H_2O$ (gypsum) or $CaCl_2.2H_2O$. The latter amendment is more efficient, requires less water to effect reclamation but is more expensive. All amendments require water to move them through the profile. This becomes a major barrier in arid regions.

If the soil has a source of Ca, e.g., $CaCO_3$ (lime) reclamation can be accomplished by adding an acid source which would dissolve the carbonate and release Ca. The most common acid sources are H_2SO_4 and elemental S. The use of S requires the oxidation of S(S valence = 0) to SO_4^{2-} (S valence = 6) which forms H_2SO_4. The use of S may be the most cost effective but it requires considerable time.

Doering and Willis (1975) studied the chemical treatment of a highly dispersed, smectite-dominated sodic soil in the laboratory with gypsum and the more soluble $CaCl_2$ and found that the calcium chloride was more effective. On the other hand, Dollhopf et.al.(1980) investigated the use of gypsum and several other chemical amendments on sodic mine spoil in Montana under favorable precipitation and irrigation conditions and found little improvement of the soil chemical conditions. He also did not detect the upward movement of Na. S.D. Merrill et.al. (1983) studied the benefits of treating sodic mine spoil in North Dakota with gypsum and topsoil. They found that the use of 10 tons of gypsum per acre of spoil, which had SAR values of 11-27, improved the forage yield per acre by only 23%. The spoil SAR values were reduced by 17-35% but the soluble sodium concentration in the root zone increased due to the upward flux of soil moisture under natural field conditions. Upward Na migration appears to be a problem in low permeable montmorillonite spoils such as these in North Dakota.

The amount of topsoil required to adequately treat saline-sodic mine spoils is difficult to determine. Sandoval et.al. (1973) found that as little as 2" of good quality topsoil spread over sodic spoils with SAR values of 25-30 increased water infiltration, reduced surface crusting, and reduced runoff. Power et.al.(1976) found that after three years of growth the forage yield of the same areas was five times that of non-topsoiled areas. Areas on which the same amount of topsoil had been mixed into the top 7" of spoil showed no beneficial effects. The conclusions from this work were that the thin topsoil acted as a permanent mulch which aided germination, reduced surface sealing and increased infiltration. Power et.al.(1976) also investigated the effect on grass yield of increasing thicknesses of soil spread over other mine spoils with SAR values of up to 26. They found that increasing the soil thickness from 4" to 12" increased the yield by 24%. Increasing the soil thickness by another 8" to a total of 20" added only 9% to the grass yield after the first year.

A problem with topsoiling and revegetating saline-sodic mine spoils is that over time the salinity of the topsoil can increase due to the upward migration of the soluble salts in the mine spoil. Merrill et.al.(1983) found that this effect was increased by adding gypsum to the underlying spoil which increased the soluble Na content at the spoil/topsoil interface. This effect suggests that the long-term benefit of topsoiling saline-sodic mine spoils may be doubtful, particularly on south and west facing slopes where the evaporation and transpiration are the greatest. This would indicate that even though the addition of thin topsoil covers will give immediate and significant increases in revegetation cover levels, the thickness of the topsoil should be increased as much as possible to allow for the eventual deterioration of the topsoil chemistry.

The results of the investigations to date on the Topaz Mine dumps and pits would indicate that the soils derived from the mine spoils are chemically and structurally detrimental to direct revegetation of the spoils. The salinity and, to a lesser degree, sodicity create phytotoxic conditions. This condition seems to diminish with time under the influence of weathering but the resulting soil structure is still adverse to plant growth after a period of up to 16 years. Work by others at this scale indicate that the chemical treatment and direct seeding of the mine spoils would likely be futile (this is verified by the test plot cover densities).

The only other alternative would be to cover the spoil surfaces with topsoil but unless a significant thickness (18-24") were applied the long term benefit of this practice is doubtful. The problem with this approach is that to date topsoil has not been stockpiled from the areas currently covered with mine spoils. Initial observations of the areas immediately surrounding the existing dumps and pits suggest that it is unlikely that a significant amount of topsoil can be reasonably obtained to adequately topsoil the existing disturbances. Faced with these facts, and the fact that the past revegetation test plot work has not resulted in acceptable levels of vegetation cover, it is reasonable to request a variance from the revegetation requirement of the DOGM. This variance would apply to all existing areas where the tuff is either exposed by mining or where the tuff comprises a significant amount of the surfaces of the dumps. This would be determined by additional sampling and field observations as needed.

Future mine disturbances should be accompanied by topsoil stockpiling, where it is available, which can be applied over the new mine spoils. The objectives of re-spreading this topsoil should be agreed to in advance by Brush Wellman and the State. Such objectives should consider the realistic possibility that, where spread over saline-sodic mine spoils, the topsoil salinity may increase over time and that the long-term vegetative cover levels may therefore be significantly lower than the surrounding undisturbed areas. This can be accommodated by the DOGM accepting a cover level that is less than the present requirement of 70% of surrounding native vegetation cover. This problem of salinity increases in the topsoil cover could be reduced by the practice of covering new dumps with non-mineralized rhyolite which is not saline-sodic in chemistry.

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SOIL TESTING LABORATORY
Utah State University UMC 48
Logan, Utah 84322

SOIL TEST REPORT
and
FERTILIZER RECOMMENDATIONS

Date received 2/7/77

Payment received $ 0

Balance due $ 24.00

Name Division of Oil, Gas, & Mining Brian W. Buck

Street 1588 W. North Temple

City, State Salt Lake City, Utah 84116 ZIP

Your USU Extension Agent Paul Daniels
444 So. 300 W.
SLC, Ut. 84101

533-5745

USU [illegible] 521-7164

LABORATORY REPORT

1185

Lab. No.	Sample No.	Crop	Soil Texture (Estimated)	Lime	pH	Soluble Salts EC_e	Organic Matter %	Plant Nutrient Index: Nitrate ppm N	Phosphorus ppm P	Potassium ppm K	
[illegible]	1	grass	Sandy Clay	+	7.8	5.2			1.2	>320	Fluen 2" [illegible]
[illegible]	2	"	Sandy Clay	+	7.8	5.6			.1	89	Roadside 6" [illegible]
[illegible]	3	"	Sandy Clay	+	8.4	7.4			1.2	>320	Fumn 6"
	4	"	Sandy Clay	+	7.5	9.1			.6	84	Blue Chalk 2" [illegible]
	5	"	Sandy Clay	+	8.1	4.0			1.1	83	Roadside 2"
[illegible]	6	"	Sandy Clay	+	8.1	2.7			.6	75	Blue Chalk 6"

ATTENTION GROWERS

These fertilizer recommendations are based on the soil analysis results, the information you supplied on the Description sheet, and on the average growing season for your area. They are guides developed from the best available scientific data, but may require some modification for your specific situation. Consult your Extension Agent for more details.

Remember that a high yield goal can be attained only when proper fertilization is used in combination with crop production management and climatic conditions consistent with that yield goal.

USU POLICY

It is the policy of the USU Soil Testing Laboratory to recommend only those nutrients that offer a reasonable possibility of increasing the yield of your crops, and in those amounts that should be necessary to achieve your yield capability. Ranges of nutrients are sometimes given, to permit some farm operator judgement.

FERTILIZER RECOMMENDATIONS FOR 19 77 CROP

Sample No.	Pounds of Nutrient per acre: Nitrogen (N)	Phosphorus (as P_2O_5)	Potassium (as K_2O)	Other	*Special Notes

*See referenced notes on the back of this sheet for explanations and special instructions.

Lime is present in all samples. Salt will likely affect germination in all samples exept possibly No.6. Plant salt-tolerant varieties. pH and high salt together indicate a probable sodium problem (poor infiltration rates, possible toxicity to some varieties). Phosphorus is extremely deficient and will be required--at least 100 lbs. P_2O_5/acre.

Potassium is very high in 1 &3 probably OK in the others. Some N will be needed: 35-50 lb N/acre, depending on available moisture.

UTAH STATE UNIVERSITY · LOGAN, UTAH 8432

SOIL, PLANT and WATER
ANALYSIS LABORATORY
UMC 48

RECEIVED
AUG 25 1978
DIVISION OF OIL, GAS, & MINING

File :- Brush Wellman's Topaz Project

August 23, 1978

Route & File in Brush Wellman ACT/023/003

Division (
1588 W. N(
Salt Lake City, Utah 84116

Data report on soil samples logged in 8/11/78.

1-6" depth

	Ident		pH	ECe mmhos/cm		NaHCO$_3$-P ppm	NaHCO$_3$-K ppm	Lime	Est. Texture	meq/l in Sat. Extract Ca + Mg	Na	SAR
	1A	Blue Chalk Dump	8.1	1.0		4.0	218	0	Clay	1.2	9.1	+12
Slope	B		8.0	.8	Salt	3.7	>320	0	Clay	.7	7.4	+13
	C		7.4	8.9	Tolerant	3.7	277	0	Clay	24.6	65.2	19
	D		7.4	4.9		2.5	>320	0	Clay	14.3	33.0	23
	2A		7.3	45		4.2	>320	+	Clay	139	313	38
Top	B		7.5	30	Salt	3.3	268	++	Clay	93.6	196	29
	C		7.3	57	Toxic	3.7	228	++	Clay	215	374	36
	D		7.8	22		4.0	187	++	Clay	75.1	134	22
	3A	Roadside Dump	7.9	8	Salt Tolerant	3.0	>320	+	Sandy C Loam	10.8	60.4	26
Slope	B		7.8	16	Salt	3.5	>320	+	Sandy Loam	31.7	123	31
	C		7.6	31	Toxic	5.0	>320	+	Sandy C Loam	103	200	28
	D		8.0	46		3.7	>320	++	Clay Loam	148	322	38
	4A		8.4	.8		4.7	>320	+	Sandy Loam	1.3	7.8	9.6
Top	B		8.3	.7	Salt	4.8	>320	0	Sandy C Loam	.7	7.4	+13
	C		7.5	9.7	Tolerant	4.4	>320	0	Sandy Loam	43.3	65.2	+14
	D		7.7	1.9		5.8	>320	0	Sandy Loam	2.9	15.7	+13
*	V		7.9	4.2		45	40	++	Sandy Loam	31.5	21.3	5.4

Marginal to low

Adequate

Serious problems w/ toxicity and infiltration (+ some problem)

0

Comments:

pH. All are in normal range, although 4A and 4B are higher than most.

ECe. Salinity lab interpretation: 0-2, negligible effect; 2-4 sensitive crops affected; 4-8 many crops affected; 8-16 only tolerant crops; above 16 toxic to most domestic crops.

NaHCO$_3$-P. (phosphorus) All except 4V are marginal to low, even for grasses.

NaHCO$_3$-K. (potassium) All except 4V have ample K. No. 4V is very low.

Lime. None needed on any sample

SAR. (sodium adsorption ratio, calculated from Ca + Mg and sodium in the saturation extract). 0-10 usually not a serious problem; 10-15 some problems on some soils; above 15 usually appreciable to serious problems with toxicity, water infiltration rate, etc.

* Vipont Mine Sample

UTAH STATE UNIVERSITY · LOGAN, UTAH 84322

SOIL, PLANT and WATER
ANALYSIS LABORATORY
UMC 48

August 1, 1985

JBR Consultants Group
2556 East Oak Creek Circle
Sandy, UT 84092
(801) 943-4144

Soil samples received July 3, 1985.

							ppm				
USU log #	Ident.	pH	ECe	SAR	SP	ESP*	P	K	Ca	Mg	Na
85-2032	BW 1	8.1	7.8	29.20	50.1	30.46	<.5	489	83.5	42.0	1310
2033	2	8.7	.8	14.83	48.8	18.20	<.5	444	5.5	1.5	152
2034	3	8.4	4.3	28.82	46.2	30.18	<.5	468	24.6	10.7	3650
2035	4	7.9	24.5	29.55	42.1	30.71	<.5	537	612.0	331.0	3650
2036	5	8.1	.5	6.10	53.1	8.38	<.5	287	10.3	4.9	95
2037	6	8.3	.3	5.06	59.8	7.05	<.5	205	7.3	2.7	63
2038	7	8.4	.6	7.88	49.1	10.57	<.5	489	7.2	3.2	101
2039	8	8.5	.5	7.69	45.1	10.34	<.5	501	11.0	2.4	108
2040	9	8.9	.6	11.30	44.2	14.49	<.5	465	6.8	1.6	126
2041	10	8.2	1.0	8.86	63.8	11.73	<.5	399	14.8	6.6	163
2042	11	8.3	.7	7.65	24.9	10.29	<.5	371	10.3	4.7	118
2043	12	7.8	29.4	42.80	83.9	39.10	.6	507	555.0	279.0	4950
2044	13	7.7	21.0	5.39	70.5	7.48	.5	114	4480.0	620.0	1450
2045	14	8.0	9.1	21.79	84.1	24.63	1.2	231	213.0	86.0	1490
2046	15	8.0	11.4	22.59	77.7	25.31	1.7	220	292.0	115.0	1800
2047	16	7.8	10.2	18.80	78.2	22.00	.7	214	298.0	120.0	1520
2048	17	7.7	10.7	16.45	82.4	19.79	.9	208	364.0	142.0	1460
2049	18	7.8	11.4	14.96	84.4	18.33	.6	201	468.0	179.0	1500
2050	19	8.5	.5	5.34	107.6	7.42	<.5	256	7.6	2.2	65
2051	20	8.3	1.3	12.68	83.4	15.98	<.5	205	13.4	5.1	215

USU log #	Ident.	pH	ECe	SAR	SP	ESP*	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	VC (% Sieves)	C (% Sieves)	M (% Sieves)	F (% Sieves)	VF (% Sieves)	T (% Sieves)
85-2052	BW 21	7.9	2.3	14.92	82.4	18.29	.5	195	30.6	12.1	385						
2053	22	8.5	.9	6.00	77.8	8.26	.5	167	24.9	7.2	132						
2054	23	8.2	1.4	5.90	76.2	8.13	.5	115	43.3	12.8	172						
2055	24	8.5	.9	5.82	34.9	8.03	3.0	421	32.9	7.1	141	3.2	3.5	2.6	9.6	18.7	37.6
2056	25	7.7	11.3	22.28	94.3	25.05	.5	477	260.5	213.0	2000	-	-	-	-	-	--
2057	26	8.4	.4	6.87	77.0	9.34	.6	138	5.5	2.0	74	-	-	-	-	-	--
2058	27	8.5	.5	3.33	24.7	4.76	2.5	334	18.6	6.8	66	3.5	6.6	5.3	10.5	8.3	34.2
2059	28	8.7	.5	3.63	23.7	5.16	1.8	276	16.4	6.2	68	9.0	12.4	7.0	11.3	9.6	49.3
2060	29	9.8	.6	9.09	32.9	12.00	1.9	104	12.2	2.3	132	51.1	31.2	1.9	3.3	2.9	90.4
2061	30	9.3	.4	5.35	28.3	7.43	.5	129	9.1	5.3	82						
2062	31	8.6	128.0	152.56	33.1	69.59	.5	318	384.0	590.0	20400						
2063	32	8.1	13.0	23.55	77.8	26.10	.5	135	327.9	210.0	2220						
2064	33	8.1	6.6	15.56	40.9	18.92	.5	249	166.3	60.0	920						
2065	34	8.4	1.1	4.47	27.4	6.28	.5	108	49.3	11.5	134						
2066	35	8.1	5.6	7.20	45.0	9.75	4.5	406	444.0	72.0	620						

* $$ESP = \frac{1.5(SAR)}{1 + .015(SAR)}$$

Sieves:

- VC Very Coarse
- C Coarse
- M Medium
- F Fine
- T Total

For further explanation see enclosed Key to Abbreviations.

kfm

Dee James

This page is a reference page used to track documents internally for the Division of Oil, Gas and Mining

Mine Permit Number M0230003 Mine Name Topaz Mining Property
Operator Bruhman Wellman, Inc Date 1-12-1987
TO ______ FROM ______

__CONFIDENTIAL __BOND CLOSURE __LARGE MAPS X EXPANDABLE
__MULTIPUL DOCUMENT TRACKING SHEET __NEW APPROVED NOI
__AMENDMENT _OTHER______

Description YEAR-Record Number

__NOI x Incoming __Outgoing __Internal __Superceded

Report on Investigations
2 Copies

__NOI __Incoming __Outgoing __Internal __Superceded

__NOI __Incoming __Outgoing __Internal __Superceded

__NOI __Incoming __Outgoing __Internal __Superceded

__TEXT/ 81/2 X 11 MAP PAGES __11 X 17 MAPS __LARGE MAP

COMMENTS: ______

CC: ______